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Effects of the Weight loss Treatment on Selected Kinematic Gait Parameters in Obese Women

by
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The objective of this study was to investigate whether a 3-month weight reduction treatment influences gait in obese women. Gait parameters were measured on a 10-m long instrumented walkway consisted of very soft wire netting fixed to the floor. The study group included 52 obese women (age: 18-57y; 37,3±11,2; BMI: 30,1- 45,8 kg/m^2; 36,5±4,8). Anthropometric measurements were taken, BMI was calculated, body composition was analyzed, selected kinematic gait parameters [mean velocity of gait, number of gait cycles per minute (cadence), stride length, gait cycle (stride time), stance time, swing time and double support time] were measured at baseline and after a 3-month weight loss treatment.

Average weight reduction of 7,4% of initial body weight resulted in characteristic changes of gait parameters among obese women: they walked faster, made more steps per 1 minute, stride length and swing duration increased, whereas cycle time, stance and double support phases were shortened. Reduction of body mass in obese individuals has positive effects on gait kinematics. Even though the treatment lasted only 3 months it resulted in significant changes of all gait parameters tested.

Key words: *obesity, weight reduction, gait, locomotion, kinematics*

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Introduction

Walking is a fundamental mode of human locomotion and physical activity, characterized by smooth, regular and repeated movements. The movements involved in walking appear to be relatively simple, yet kinesiological analysis shows them to be extremely complex. However, once learned, it soon becomes a fully automatic motor activity which is performed without involvement of our awareness (Hamilton and Luttgens 2002). Though walking is performed almost unconsciously and largely automatically, there are several sources of information which help the subject to control walking such as inputs from the visual, vestibular and proprioceptive systems which adequate muscle strength, appropriate neuromuscular timing and free passive joint mobility (Prince et al. 1997). To make a step we need to move the body outside the base of support and at the same time prevent falling. This may be achieved due to the trajectory of the swing limb which will achieve balance conditions during the next stance phase (Winter 1995). In each gait cycle there are two periods of double support and two periods of single support. The stance phase usually lasts about 60 % of the cycle, the swing phase about 40 %, and each period of double support about 10 % (Murray 1967).

The sustained repetition of load cycles in walking make significant demands on the musculoskeletal apparatus even in normal-weight individuals (Rohrle et al. 1984). Based on Newton's Laws of Motion it would appear reasonable to hypothesize that obese individuals will experience greater loads on their joints than normal-weight individuals (Hills et al. 2002).

The force of walking is ground reaction force produced by extension of the lower extremity against a resistive surface. Because walking is an alternating pendular motion of the lower extremities, the inertia of the body must be overcome at every step. The amount of force needed to alter the object's velocity is directly related to the amount of inertia it has. The measure of inertia in a body is its mass. The greater the mass of an object, the greater the inertia (Hamilton & Luttgens 2002).

Obesity is recognized as a major health problem in many parts of the world and the incidence of the condition is escalating at an alarming rate (WHO 1998). This global trend of increasing obesity prevalence indicates that current measures in the prevention, treatment and management of the condition are ineffective. Obesity significantly increases the risk of developing numerous medical conditions, including hypertension, stroke, respiratory disease, type 2 diabetes, gout, osteoarthritis, certain cancers and various musculoskeletal disorders, particularly of the spine and lower extremities (Must and Straus 1999).

There is a limited number of studies focusing on the influence of overweight or obesity on locomotion function (Spyropoulos et al 1991, Hills et al. 1991, McGraw et al. 2000, Messier et al. 1996). These findings indicate that obese subjects have a slower, safer and more tentative walking gait and display a longer double support and shorter swing phase when compared with normal-weight individuals. However, there have not been any studies done on the effects of weight loss treatment (WLT) on gait characteristics.

Considering the above a study was designed to determine the differences in gait variables in obese women before and after the WLT.

Material and Methods

A total of 52 obese women participated in the study, mean age: 37,3 ± 11,2 (18-57y), mean BMI: 36,5± 4,8 (30,1 – 45,8 kg/m^2). Obesity was defined as BMI ≥30 kg/m^2, waist circumference of ≥ 88cm and fat mass content of ≥30%. All women gave their signed informed consent before participation in the study. Subjects were told that they could withdraw from the study at any time. The study was approved by the Senate Ethics Committee of the Academy of Physical Education in Katowice.

Stature was measured without shoes with a stadiometer. The Tanita Body Fat Monitor (300P) type was used for weighing and for body composition measurements using Bioelectrical Impedance Analysis (BIA). All subjects were weighed in light clothing. Additionally, waist circumference measurements were performed with a flexible tape measure to confirm diagnosis of obesity. The measurement was performed at the mid distance between lower costal arch and superior iliac crest, with the measuring tape being positioned perpendicular to the spine. Lower extremity length (the distance from trochanter major to lateral malleolus) was measured for the purpose of leg-length discrepancy screening (<0,5cm).

Obese women participated in a 3-month WLT, during which, every two weeks, they attended consultation meetings with physicians, dieticians, psychologists and physical therapists. At the meetings, patients were also encouraged to obey a low-calorie diet (1000-1200 kcal/day), increase their daily physical activity and additionally perform activities such as walking, biking, swimming etc. 3-5 times per week for 30-60 minutes.

Body mass, waist circumference, fat content and gait data were recorded twice, before and immediately after the completion of the WLT.

All subjects had no neurological disorders, balance-related pathological condition or walking impairment, which was determined by a screening evaluation performed by licensed physical therapist in order to ensure that subjects were in good health and had sufficient mobility and strength for gait. Subjects demonstrated sufficient trunk mobility in all planes and complained of no functional limitations in trunk movements. They demonstrated the mean lower extremity range of motion (ROM) needed for normal gait at the hip, knee and ankle joints as reported by Murray (1967). All participants exhibited Good to Normal muscle strength throughout both lower extremities based on standard manual muscle testing (Daniels and Worthingham 1980). The subjects participating in the study were without appreciable leg-length discrepancy (<0,5cm),

The method used in this study was adopted form the study performed on quadruped locomotion, which was published in Acta Neurobiol Exp (Afelt et al. 1983, Blaszczyk and Dobrzecka 1989).

The gait parameters were measured on a 10-m long instrumented walkway which consisted of very soft wire netting (one meter wide and ten meters long) fixed to the floor. The ends of the platform were connected to a low voltage direct current circuit. One end of the net was grounded, while the other was coupled to a 80 mV source so that the linearly increasing potential from 0 to 80 mV was obtained along the walkway. The contact electrodes used in this experiment were made of soft copper lines. All the electrodes were identical and fixed precisely to the soles of subjects' shoes. The arrangements and dimensions of the electrodes were chosen in such a way that they did not disturb locomotion. The electrodes were coupled with a connector fixed to the belt of each subject. The subject trailed an electrical cable, which connected the foot contacts to a computer. Voltage signals from the electrodes were applied to the inputs of a six-channel, low input resistance direct current amplifier. The output signals from the amplifier were fed to a computer.

Stance phases were recorded as a square pulse whose amplitude was proportional to the distance along the walkway (i.e. the voltage at that point) and its width depended on stance duration (Fig 1). The interval between successive pulses (the baseline) indicated swing the phase. The difference between the amplitudes of two consecutive pulses for a particular limb determined stride length.

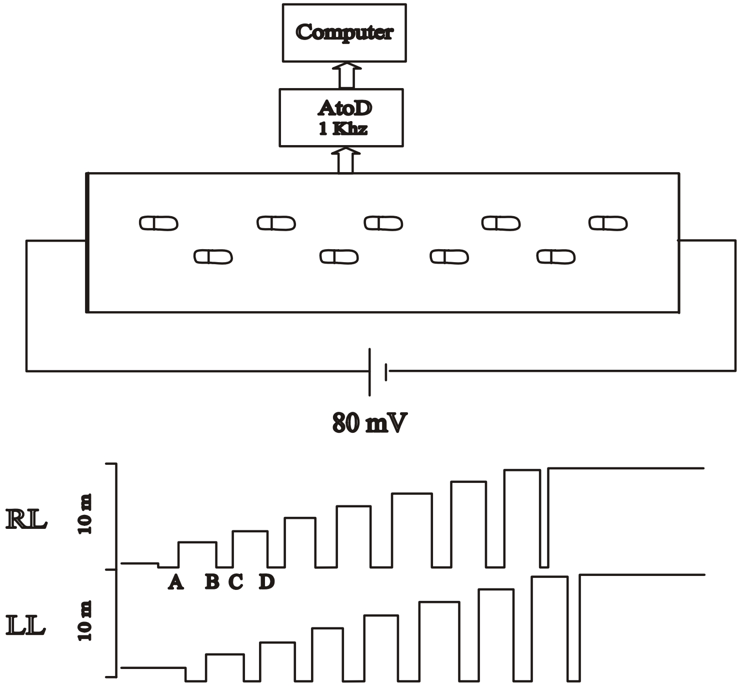

Fig. 1

The experimental setup (upper panel) and typical gait diagram (lower panel) recorded for walking subject; RL – right leg, LL – left leg, AB and CD limb contact (stance) pulses, BC - swing phase. The amplitude of the stance pulse determines the distance between point of a limb contact on the pathway in relationship to the end of the path. The difference between the two successive amplitudes is a measure of the stride length.

Such a sequence of pulses recorded simultaneously for two limbs created a gait diagram (Fig.1) allowing for calculation of the following gait parameters for each lower extremity:

mean velocity of gait [m/s], cadence [number of gait cycles per 1 minute], stride length [m], gait cycle (stride time) [s], stance time [s] % of gait cycle, swing time [s] % of gait cycle, double support time [s] % of gait cycle.

Stance, swing and double support time were primarily calculated in seconds, but afterwards they were expressed as percentage of a total gait cycle constituting the value of 100%.

For all individuals, irrespective of size and shape, a comfortable self-selected speed of walking is commonly less variable than any imposed walking speed, either slow or fast. (Hills et al. 2002). Therefore after the initial examination all subjects were asked to walk along the walkway at their own carefully determined comfortable walking speed. Subjects were instructed: "Please walk at your normal speed, neither fast nor slow". Although the walkway was 10 m long, the data were analyzed in the central portion of the walkway in order to eliminate initiation and termination phases of gait. For this purpose three initial and terminal steps of each individual were excluded from the analysis. All parameters were measured both for right and left lower extremity. There were no considerable discrepancies between right and left lower extremity parameters, therefore gait symmetry was assumed for the sake of simplicity in data analysis.

The statistical analysis included the calculation of the means and standard deviations (SD) of the gait parameters for obese and lean subjects for all 10 distances covered. The Wilk-Shapiro test of data distribution showed normal distribution of all parameters, therefore student T-test for dependent variables was used for the comparison of differences between anthropometric measurements (body mass, BMI, waist circumference) and gait parameters before and after the WLT. The *p* value of less than 0.05 was considered to represent statistical significance. All statistical analyses were performed using Statistica (v. 6,0) software, Statsoft U.S.A.

Results

Summaries of mean and standard deviations of the anthropometric data for obese women before and after the WLT are presented in table 1. The average value of weight loss during the 3-month WLT amounted to a mean of –7,3 kg, with weight loss range from –24,6 to 0kg, (in relative values respectively –7,4% (-21,9 – 0%). Differences of body mass, BMI, waist circumference and fat tissue content between initial and final examination were all of statistical significance (p<0,001).

Table 1

Age, body mass, height, BMI and waist circumference of obese women before and after the weigh loss treatment (means, standard deviations and range)

	N	age [yrs]	height [cm]	body mass [kg]	BMI [kg/m^2]	waist [cm]	fat tissue [%]
before treatment	52	37,3±11,2 (18 - 57)	163,1 ± 6,2 (150 – 178)	97,7 ± 12,8 (71,1 – 124,1)	36,5 ± 4,8 (30,1 – 45,8)	106,1 ± 10,2 (88 – 127)	44,9 ± 3,8 (36,9 – 54,2)
after treatment				90,4 ± 12,8 (64,9 – 124,1)	34,1 ± 4,8 (24,4 – 44,5)	99,3 ± 10,5 (81 – 127)	41,5 ± 4,8 (30,4 – 52,5)
p				0,001	0,001	0,001	0,001

Analysed kinematic gait parameters and cycle times for obese women before and after the WLT are presented in table 2. Student T-test for dependent variables showed statistical differences for all analyzed parameters. After the WLT obese women walked faster (p<0,05), made more steps per 1 minute (p<0,01), their stride length and swing time increased (p<0,05) whereas their cycle time, stance and double support time shortened (respectively p<0,01, p<0,01 and p<0,05).

Table 2

Means, Standard Deviations and T-test test for kinematic parameters of obese women before and after weight loss treatment

	velocity [m/s]	cadence [steps/min]	stride [m]	cycle time [s]	stance time [%]	swing time [%]	double support time [%]
before	1,07±0,2	105,25±10,47	1,21±0,14	1,15±0,12	65,88±1,92	33,99±1,93	15,99±1,95
after	1,12±0,22	107,78±11,72	1,24±0,15	1,13±0,13	65,37±2,04	34,48±2	15,52±2,02
p	0,05	0,01	0,05	0,01	0,01	0,05	0,05

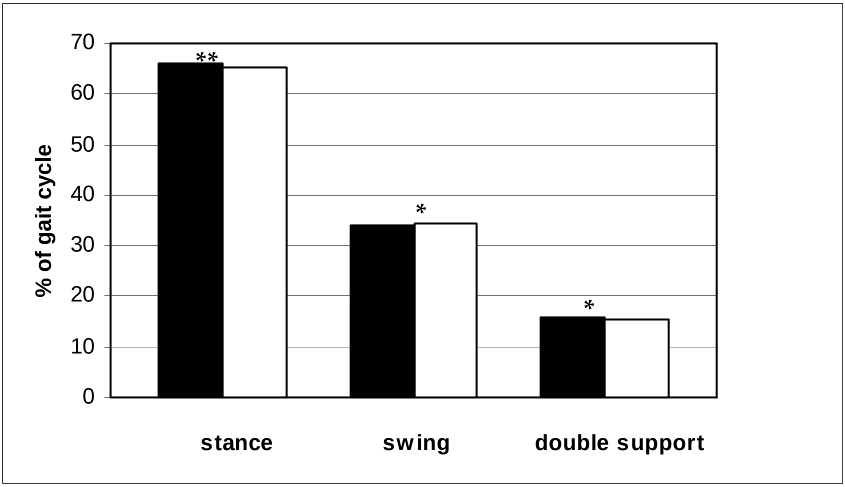

Fig.2

*Gait variables as percent of gait cycle in obese women: ■ before WLT; □ after WLT, (**p<0,01, *p<0,05)*

Discussion

The maintenance and possible improvement of functional mobility should be one of the most important objectives in the treatment of an obese individual. Excessive amount of adipose tissue plus increased loads on the weight-bearing joints may lead to inefficient body mechanics, pain, discomfort, and affect mobility, including locomotion. Such movement difficulty may perpetuate the viscous cycle of obesity by predisposing obese patients to sedentary lifestyle. Without exception, each cause of motion is a form of force. If an object in motion is seen (a man walking), it is obvious that it is moving because a force has acted on it. It is well known, that the force must be significantly greater to overcome the object's inertia, such inertia is definitely larger in obese individuals, so the acting force must be adequately higher in obese individuals (Hamilton & Luttgens 2002).

A primary objective of this study was to determine whether the gait characteristics of obese women was different after the WLT. The velocity of walking, is the parameter most often described by all gait researchers, since all gait parameters depend on its value. When the gait velocity increases, the swing phase become proportionally longer and the stance phase and double support phases shorter (Murray 1967). This study showed that the average weight loss of 7,3kg (7,4%) of original body weight resulted in increased walking velocity of obese women, which was accompanied by shorter stance and double support time and by longer swing time. It was assumed that the observed changes of the remaining measured gait parameters (the increased cadence and stride, and shorter gait cycle) also resulted from gait velocity increase after the WLT. The observed differences in gait parameters seem to be not of great value, though each of these small differences need to be multiplied by the average of 6,000 to 8,000 steps an adult makes each day (Leermakers EA et al. 2000).

Increased weight of lower extremities results in requirement for increased propulsive forces during gait. This constitutes an extra challenge for locomotor system of obese women. Such conclusion was made by Messier et al (1996), who studied gait of obese subjects on a force platform which was mounted within a walkway. They found that braking and propulsive forces increase as the subject becomes more obese and suggested that reduction of these forces may be accomplished either by decreasing stride length or body mass. These findings are in agreement with Spyropoulos's theory (1991) of increased push-off force adequate to increased body mass during walking. Browning and Kram (2007) found that obese subject have greater sagittal-plane knee moments than normal-weight adults and they concluded that slower walking in obese reduces ground reaction forces and net muscle moments and may be a risk-lowering strategy for obese adults who wish to walk for exercise and prevent musculoskeletal pathology, particularly knee osteoarthritis.

Doke Jiro et al (2005) measured work performed on the lower extremity during gait, and measured metabolic cost of 12 healthy young adults subjects and concluded that moving legs back and forth at a typical stride frequency of 0,9Hz might consume about as much as one-third of the net energy needed for walking at 1,3 m/s. Therefore it may be assumed that energy required to swing lower extremities of obese would be higher than 30%. Perhaps this is why obese women from the present study were able to walk faster after the WLT.

Studies done by Katch et al (1988), Saibene & Minetti (2003) and Foster et al. (1995) confirm that excessive amount of adipose tissue also increases energy output due to increased body inertia making the locomotion of obese less efficient. Increased energy expenditure is required in obese to overcome friction between thighs, arms and torso and to perform clearance maneuvers (legs and arms swinging wide to move around thighs and torso, respectively).

There is no information available in the literature concerning the effects of weight loss on gait characteristics, however gait changes of similar characteristics as found in obese women before the WLT (shorter swing duration and decreased stride length) were observed in subjects who were carrying additional load (Ghori and Luckwill 1985, LaFiandra et al. 2003). Moreover, reversed gait alternations (decreased stance and double support time) were observed in healthy subjects whose weight was supported by a modified climbing harness (Finch et al 1991). These findings indicate that changes in body weight do have influence on gait kinematics.

Considering the above, it may be concluded that obese individuals have to carry excessive amount of body mass, so the force needed to transfer heavier body will be proportional to the body mass. It may be also hypothesized that joints of obese individuals would be subjected to greater loads during locomotion. High levels of body fat plus increased loads on the major joints has the potential to lead to many of the orthopedic conditions characterized by pain and discomfort, inefficient body mechanics and further reductions in mobility. Owing to the progressive nature of such developments, it may be reasonable to hypothesize that the longer the obesity exists, the more likely one is to develop musculoskeletal pathology in weight-bearing joints (Hills et al. 2002). Therefore the effective weight reduction treatment in obese seems to be very desirable not only because of the well-known health benefits, such as reduction of cardiovascular disease risk, but also due to improved conditions of fundamental mode of human locomotion.

The analyzed kinemtaic gait variables do not provide direct insight into the underlying causes of movement disorder (e.g. force). Kinematic parameters are easiest to obtain in clinical setting, but do not constitute a complete gait analysis, since they only provide information regarding patient's attempts to compensate for some pathological processes.

It may be concluded that reduction of body mass in obese individuals has positive effects on gait kinematics, though a complete gait analysis (ground reaction forces, electromyography) would have to be done to find the underlying cause of observed gait changes after the weight reduction process.

Conclusions

Reduction of body mass in obese women of 7,4% of initial body weight has positive effects on gait kinematics.

Observed gait changes may help obese women to increase their physical activity which may constitute a important factor in management of obesity.

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